Transient Grating Photoacoustics on a Silicon Chip

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In the past decade, laser-induced thermal and acoustic transient gratings attracted considerable attention in the context of the non-destructive characterization of thermophysical properties of thin solid films. While the usefulness of transient grating measurements in a laboratory is well proven, can they be used for thin film process control on a product line making computer chips? A success in a "real-world" application depends on whether a new technology is mature enough for use in the industrial environment and, on the other hand, on whether the industry has a real need that cannot be satisfied by traditional measurement techniques. Our discussion will concentrate on one particular application area, i.e. metal interconnects on silicon-based integrated circuits (ICs). With the continuous drive to increase circuit speed and reduce feature size, metal interconnects become increasingly critical for the performance and reliability of the ICs. The transition from interconnect structures based on aluminum and SiO2 to copper and novel "low-k" dielectrics has created metrology challenges that can no longer be met by traditional electrical resistance measurements on "monitor" wafers. A compact and robust transient grating apparatus incorporated into a commercial high-throughput measurement station provides a precise tool for non-contact measurement of copper thickness on product wafers as they move through an IC factory. The measurement is based on surface acoustic waves while other components of the transient grating signal help extend the measurement capabilities for specific applications. We will review the state-of-the-art copper interconnect fabrication process and discuss specific challenges and opportunities for the photoacoustic metrology posed by process steps such as barrier and seed deposition, electroplating, and chemical-mechanical polishing. While the focus of the process control applications has been on film thickness measurements, there are other unique opportunities for the characterization of material properties. The transient grating technique probes both acoustic and thermal responses of thin film structures which makes it suitable for measurements of mechanical properties such as speed of sound, density, and elastic constants as well as thermal properties such as thermal conductivity. For metals with high electron mobility such as Cu, electrical and thermal conductivities are linked to each other, which led us to a method of the simultaneous and independent measurement of the resistivity and thickness of copper films. Another application area to be discussed is the characterization of the elastic properties of low-k dielectrics. The presentation will be concluded by a discussion of potential new developments in the laser photoacoustics of solids and its applications.